AD-A139 802 RECOMMENDATIONS FOR THE INTERAGENCY SHIP STRUCTURE COMMITTEE'S FISCAL 1985 RESEARCH PROGRAM(U) NATIONAL RESEARCH COUNCIL WASHINGTON DC MARINE BOARD 1984 1/1

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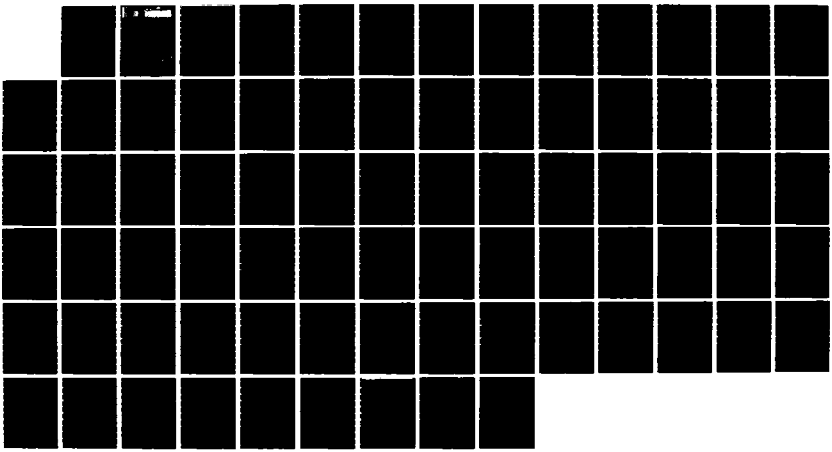

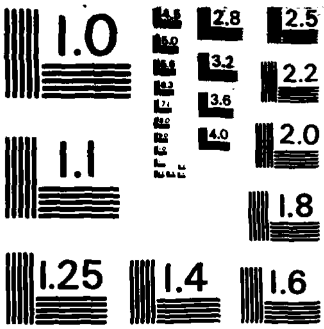

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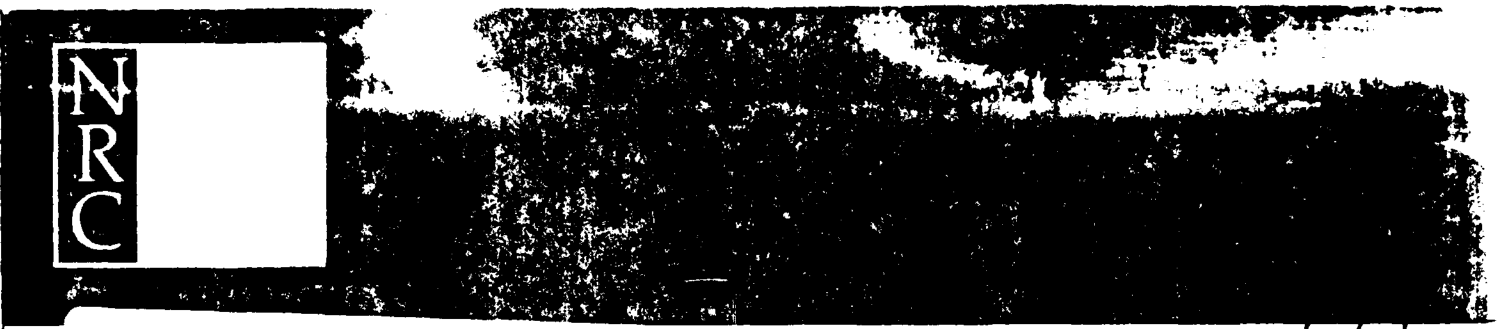

Recommendations For the Interagency Ship Structure Committee's Fiscal 1985 Research Program

Committee on Marine Structures

Marine Board

National Research Council

COMMITTEE ON MARINE STRUCTURES

Of The

Marine Board
Commission on Engineering and Technical Systems
National Research Council

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Recommendations For the Interagency Ship Structure Committee's Fiscal 1985 Research Program

Committee on Marine Structures
Marine Board
National Research Council

NATIONAL ACADEMY PRESS
Washington, D.C. 1983

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This report represents work supported under provisions of Contract DTCG23-84-C-20005 between the National Academy of Sciences and the U.S. Coast Guard, acting for the Ship Structure Committee.

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ABSTRACT

The Committee on Marine Structures (CMS) of the Marine Board of the National Research Council provides technical services covering planning, review, and advisory relationships to the interagency Ship Structure Committee (SSC), composed of representatives from the U.S. Coast Guard, the Naval Sea Systems Command, the Maritime Administration, the American Bureau of Shipping, the Military Sealift Command, and the Minerals Management Service. This arrangement requires continuing interaction between the CMS and the SSC to assure an effective program to extend knowledge of materials, loading, response, design, fabrication, and inspection as related to marine structures. This report contains the CMS' recommended research program for five years, fiscal years 1984-1988; 12 project descriptions for fiscal year 1985; and a brief review of 18 active and six recently completed projects.

INTRODUCTION

This report, the latest in the series of the Committee on Marine Structures' (CMS) annual reports, outlines a five-year research planning program, sets forth recommendations for the interagency Ship Structure Committee's (SSC) fiscal year (FY) 1985 research program and reviews the SSC's research activities for FY 1984. The report contains four sections. This white section, the introduction, summarizes the program-related considerations and recommendation for the five-year research program plan and the plan itself. The green section presents the FY 1985 project recommendations. A review of active and pending projects comprises the yellow section, and the blue section reviews completed projects. The objective of the research program is to improve the hull structures of ships and other marine structures by an extension of knowledge pertaining to design, materials and methods of construction. The organization and operation for this activity of the CMS is described in the appendix.

The FY 1983 annual report contained a discussion linking the materials-design-fabrication triangle to the properties-stress-flaw size triangle. The FY 1984 annual report contained a recommendation that the SSC increase the scope of its planning to include offshore platforms.

This year, a steering committee, under the auspices of the CMS, held a Design-Inspection-Redundancy Symposium in Williamsburg, Virginia, and achieved substantial interdisciplinary and interindustry discussion and transfer of information. Prepared papers illustrated theoretical as well as technical applications on the integrated theme of the symposium. Within the marine structures area, such applications were portrayed as being in the initial states and in need of focused development to advance. Specific technical work requirements are being finalized by the symposium steering committee.

In addition, the Materials Advisory Group (MAG) of the CMS held a brainstorming session to identify thrust areas for future research. They noted an existing common thread among the previous reports and recommendations of pursuing the concept of fitness-for-service where fracture-control concepts were used.

Five-Year Research Program Development

Eight thrust areas for future research were developed, discussed, and agreed to by the CMS. They are reflected, where appropriate in the project recommendations for FY 1985. The Loads Advisory Group (LAG) of the CMS plans to hold a similar thrust-development session in FY 1984. The eight thrust areas identified by MAG are:

1 Marine Materials Development
2 Fracture Analysis Methods
3 Fracture Performance - Small-Scale Test Interpretation
4 Use of Fatigue Data
5 Corrosion Protection for Marine Structures
6 Significance of Weld Defects
7 Inspections
8 Residual Life

Descriptions of these thrust areas as well as programmatic recommendations follow.

Marine Materials Development

The SSC has a long history of sponsoring programs aimed at developing a better understanding of materials for marine structural applications. Over the years, these efforts have usually taken the form of characterizing material behavior in a marine environment, although composition, processing, and toughness mechanisms of a potential new ship steel were evaluated in SSC project SR-1256. In addition, fundamental property data, such as fatigue, fracture, weldability, and corrosion behavior have been developed which have provided valuable insight to designers, builders, and operators faced with having to predict material performance. This overall effort has assisted in improving the integrity and performance of marine structures.

The primary intent of SSC materials programs has been to identify critical material application parameters to assure reliable performance. In some cases, parameters unique to the marine industry have required better definition. Currently, the CMS believes it inappropriate for the SSC to develop new materials or material processes because of the SSC's limited resources and the amount of required effort. Rather, SSC should contribute to the establishment of criteria for successful performance. These criteria could then serve as goals for development programs performed by private industry. Each material supplier would then be able to offer materials optimized with regard to his unique production capabilities.

> Recommendation - SSC material programs should continue characterizing material behavior in the marine environment to identify property requirements critical to successful performance.

Fracture Analysis Methods

The SSC was established as a direct result of the World War II ship fracture problems. For over 30 years, the SSC has undertaken numerous efforts to study the problem of brittle fracture. An outgrowth of these efforts has been a much better understanding of this fundamental material and design relationship. This work has demonstrated the importance of toughness and has assisted in the development of vastly improved shipbuilding steels and fabrication techniques.

During the last 10 years, a better fundamental understanding of the fracture process has extended the available analytical techniques into the elastic-plastic region. These new methods are more applicable to marine materials used in fixed offshore platforms and pipelines. Specifically, the Crack Tip Opening Displacements (CTOD) method has been widely utilized in Britain and Europe and is beginning to be used in the United States as an important material parameter. However, a similar U.S.-developed "J" integral method has not had widespread acceptance.

An effort should be made to determine if the CTOD, or "J" integral or any other method should be recommended for wider utilization by the marine industry. It is also important that the knowledge of of marine materials behavior be integrated into applicable design methods.

> Recommendation - Future SSC programs should be directed toward establishing the technology for assuring reliable application of materials, utilizing emerging elastic-plastic analysis.

Fracture Performance - Small-Scale Test Interpretation

In general, the offshore and shipbuilding industries have learned to design safe structures. Present design standards are purposely kept simple and of broad applicability. The structure is not necessarily unsafe when one aspect of a structural design does not meet blanket design standards. Sometimes a more detailed assessment of the particular application must be made before fitness-for-service can be assured.

A major problem with the evolution of design standards is that the true margin of safety is not usually well understood. In other words, the real structural integrity may be quite different than interpreted by mechanical property or individual component tests. Yet, there is a continuing need to better evaluate structural performance, particularly when the structure is found not to meet normal fabrication standards or the in-service requirements are changed.

Fracture toughness evaluations have historically relied heavily on Charpy test results. The past few decades also have seen the introduction of other toughness measures, most of which have the ultimate aim of preventing crack initiation. However, all of these types are inadequate when one is trying to judge actual structural performance. The primary objective of the fracture performance thrust is not to change the basic test types, but rather to understand how the results relate to in situ performance.

(a) Charpy Testing

The most popular approach to fracture control of structures is the transition-temperature approach utilizing the Charpy V-Notch (CVN) test. Other fracture-toughness tests are sometimes required for weld

procedure qualification purposes, but the CVN test is the standard for production control. It is easy to perform, inexpensive, and some users suggest they know exactly what a CVN result means. For some conventional steels, satisfactory experience has indicated that the CVN is a reliable indicator of structural performance. Also, there are empirical translations of CVN results into a contemporary toughness measure (K_{Ic}). However, these relationships have much uncertainty and are particularly questionable for newer steels with high initiation toughness.

Assuming the CVN test will remain the quality-control standard for decades to come, the SSC could, through its research, enhance the basis for understanding.

(b) Crack Tip Opening Displacement

A toughness measure gaining worldwide acceptance for fitness-for-service analysis is crack tip opening displacement (CTOD). The primary advantage of this parameter is that the entire temperature transition curve may be evaluated. However, there are a number of questions which arise when trying to relate the CTOD results to actual structural performance. One question is how the results of the CTOD tests are affected by starting crack depth or crack-to-width ratio. A National Bureau of Standards' study notes that for shallow cracks or thin sections, the restraint at the crack tip is likely to be diminished to the point that the failure mode is net-section yielding rather than fracture.

For welds there is particular interest in fracture performance of the heat-affected zone (HAZ). Such zones are not homogeneous. Therefore, there is interest in determining how the toughness varies with notch orientation, distance from the fusion line, steel chemistry, and welding parameters. Another question is the effect of residual stress. All of these issues require experimentation for resolution.

(c) Crack Propagation and Arrest

It is difficult to control crack extension from isolated, locally stressed or locally embrittled regions of the structure. The low toughness values and high stresses associated with such regions (e.g., arc strikes, hard spots, defective welds, and incorrectly designed details) make it difficult to prevent the onset of crack extension. In these cases, fracture safety can be achieved by assuring that the cracks that begin to propagate in these regions (so-called "pop-ins") are arrested and contained in the surrounding, higher quality material, or by a strategically positioned crack arrester. Examples of this concept are the high toughness gunwale and shear strakes routinely installed at the corners of ship hulls and extra tough material for joint cans in fixed offshore platforms.

One relevant material design parameter is the crack-arrest toughness, K_{Ia}, which defines the combination of fastest running crack length and stress level that must be exceeded for a crack to

penetrate a structural member. About a decade has elapsed since the problems of K_{Ia} measurement and arrester design were last examined by the SSC. Since that time, crack-arrest technology has made substantial strides although problems remain with respect to measurement and application. It is noteworthy that a test method for measuring low and intermediate values of K_{Ia} is close to standardization by the American Society for Testing and Materials. Several promising approaches for measuring the large K_{Ia} values associated with tough, arrester grade steels operating on the ductile shelf have been proposed and are being evaluated. In addition, finite-element methods are available for analyzing crack arrest accompanied by large-scale yielding--the condition obtained in actual structures when a long crack is halted. For these reasons, the measurement of K_{Ia} values for marine structural steels and the analysis of promising crack arrester configurations have been identified as important for future research.

> Recommendation - SSC projects should contribute to the better understanding of the relationship to structural performance of the results of laboratory-type quality-control toughness tests such as CVN, DWTT, DT, K_{Ia}, DW-NDT, and CTOD.

Use of Fatigue Data

Many fatigue data exist for idealized and simple test load conditions. Two examples of such conditions are constant amplitude and nominal uniaxial applied stress. Loadings rarely are of constant amplitude and structural components subject to fatigue often have complex geometries. The economics of experimental work are such that full-scale testing of components under in-situ load conditions is often impractical. Hence, there will always be high interest in understanding the translation of simple test results to the real world structural performance.

(a) Variable Amplitude Loading

In structural design, the normal assumption when faced with a variable load condition is that the Palmgren-Miner (P-M) rule is valid. The rule assumes that the results are not affected by the order of variable load application (i.e., no interaction occurs) and fatigue damage is estimated by establishing the ratio of cycles (from a constant amplitude S/N curve) at the same level and summing the various ratios together. Failure is assumed to occur when the summation reaches 1.0.

It has long been recognized by the technical community that the P-M rule can be in error, particularly when there is a dramatic change in stress amplitude from one cycle to the next. Crack growth can accelerate or retard under certain conditions. However, the question of interest with ships and offshore structures is how well the P-M rule does under a random sea state condition. Recent or current

studies in the United States (e.g., Florida Atlantic University) and Europe (e.g., the Welding Institute) have begun to address the issue, but there is clearly more to be done.

> Recommendation - SSC programs should more specifically identify the need and applicability for better definition of variable amplitude fatigue performance.

(b) Biaxial Loading

Loadings in structural components are often more complex than the uniaxial loading used in fatigue.

To use simple data in multiaxial stress situations, documents, such as the ASME Boiler and Pressure Vessel Code, use an equivalent stress (range or amplitude), which is defined as the maximum shear stress or maximum octahedral stress. However one area of weakness is in defining an equivalent mean stress. The ASME code uses a uniaxial mean stress correction. Estimating an equivalent mean stress by simply summing the directional mean stresses also has been suggested, but this latter approach obviously suffers loss of credibility when the stress approaches yield stress in more than one direction.

> Recommendation - SSC programs should more specifically identify the need and applicability for better definition of biaxial fatigue performance.

Corrosion Protection for Marine Structures

Corrosion protection for structures is a major factor in the prevention of failure in a marine environment. Important economic benefits could be realized if replacement of a structure is deferred and its life extended through a better understanding of the application and performance of corrosion protection systems.

> Recommendation - SSC reviews should continue to follow corrosion protection developments as an important aspect of structural integrity.

(a) Cathodic Protection

At the present time there are two types of cathodic protection systems: 1) galvanic anodes and 2) impressed current anodes. The systems are explained in the National Association of Corrosion Engineers' NACE RP-01-76 publication entitled "Control of Corrosion on Steel, Fixed Offshore Platforms Associated with Petroleum Production." Galvanic anodes are the most commonly used method of protection in the Gulf of Mexico, but the calculation of the protection required depends on many variables. The principal factor governing the minimum current density at which polarization necessary for complete cathodic protection is achieved is the availability of oxygen at the submerged surface. The NACE document provides typical design current densities

for regions of shallow or modest water depths in the Gulf of Mexico which can be used for calculating the number of anodes necessary to provide protection. Recent tests of various galvanic anodes have revealed that the impressed current efficiency can vary depending on the composition, quality, and application of the anodes.

(b) Cu/Ni Sheathing

The feasibility of using copper/nickel (Cu/Ni) sheathing on ships was recently reported in a Society of Naval Architects and Marine Engineers HS-9 project. Despite high initial costs, the use of this material was concluded to be cost effective in the long term. Continued development of this material/application will require evaluation of: (1) non-destructive examination techniques for Cu/Ni sheathed hulls to insure underlying steel integrity, (2) the effects of weld defects, (3) the effects of sheathing pinholes, and (4) optimized installation and repair procedures.

Offshore structure splash zone requirements also should be considered. The splash zone interval on offshore platforms is protected from accelerated corrosion attack with thick coatings. Commonly used coatings are usually applied with one layer so that any damage can be repaired with one simple step. It appears that the splash zone would be an ideal place to use Cu/Ni sheathing. The use of Cu/Ni on other areas of the platform are not usually recommended because: (1) Cu/Ni sheathing on T-K-Y-shaped joints might hide defects or cracks that are detrimental to structural integrity, and (2) Cu/Ni may interfere with the galvanic protection system normally used.

Significance of Weld Defects

During the last 30 years, fracture-analysis methods have become available to predict the behavior of crack-like defects found in structures. These analytical techniques allow one to predict, with only a modest degree of confidence, the seriousness of a defect relative to the intended use of a component. With the use of sophisticated analytical techniques, rational acceptance of defects in marine structures can be accomplished. However, these analytical techniques must be corroborated by experimental tests. In addition, the analytical techniques themselves must be refined and simplified so that they can be used in design and in quality inspection plans.

The SSC has begun work on this long-range thrust area by instituting a project to determine the effect of porosity on marine welds. It is intended to study other defects such as slag, undercut, and lack of fusion.

Recommendation - SSC should continue to support studies of the variety of significant weld defects and their effects on a structure's fitness for service.

Inspections

The term "in-process inspection" refers specifically to inspection techniques that are primarily used during the fabrication process or soon thereafter. For example, in-process inspection can be used to provide on-line monitoring of a welding process by recording the relevant welding parameters or to assure fitness-for-purpose condition of a welded structure by screening out all flaws that exceed a specified standard. However, not all inspection techniques can be used for in-process inspection.

As a result of research and development efforts by the military and the nuclear power industries, a number of reliable inspection techniques have been developed to address inspection problems similar to those facing the marine and offshore industries. The new inspection techniques include non-contact ultrasonics, which is potentially capable of functioning at elevated temperatures, and real-time radiography. In addition, off-the-shelf process parameter monitoring instrumentation, now widely available, may be used to control process parameters in a closed-loop manner and to make a permanent record of the actual values. In particular, efforts have been initiated to develop quantitative techniques for estimating the dimensions and other flaw characteristics relevant to fitness-for-purpose validation of weld quality. Many of these techniques offer the possiblity of high inspection rates that may be economically compatible with high-deposition-rate welding processes.

In contrast to in-process inspection techniques, which can be specified in advance, in-service inspection techniques must often be adapted to the physical condition of an existing structure. As a result, reliable validation of the fitness for continued use of existing marine structures and vessels poses an entirely different range of problems and technical challenges than in-process inspection to fitness-for-purpose standards.

In many cases, accessibility to critical areas is severely limited by conditions that can be easily overcome in new construction. For example, inspections may have to be carried out at substantial water depths, in adverse weather conditions, and in the presence of barnacles or surface coatings that were not present when the structure or vessel was under construction. In such cases, a need exists for highly specialized instrumentation and, equally important, realistic inspection standards that properly take into account the true requirements for indicating significant flaws. Currently, most inspection techniques are not capable of providing estimates of true flaw sizes and other parameters that may influence the remaining life.

> Recommendation - SSC reviews should maintain a current awareness of the in-process construction and in-service inspection technologies that are in use in related industries with emphasis on potential usefulness in marine applications.

Residual Life

It may be possible to use the inspection finding to help calibrate the original design procedure. For example, the American Petroleum Institute contracted with Professor P. H. Wirsching (University of Arizona, Tucson) to develop a format for fatigue reliability. However, like the Munse approach developed at the University of Illinois, it needs calibration if it is to be used. Wirsching developed two approaches to calibration but, unfortunately, there is insufficient information about the structure and inspection findings to perform the calibration.

Where fatigue is concerned there is a related question concerning the lack of evidence of cracking. One might ask, "What is the probability of getting a failure before the next inspection, given that cracking was not found at the previous inspection?" This is a Bayesian probabilistic updating question although there is concern about uncertainty introduced by potential inspector error.

If cracking is found, it is important to determine why it occurred. It is also important to assess the impact of the crack on continued structural performance.

> Recommendation - SSC should establish a program to determine how to make effective use of inspection findings which includes consideration of risk analysis and impact of cracks on structural performance.

Five-Year Research Program Plan

Based on the identification of the thrust areas for future research, the CMS has realigned a portion of the five-year research plan to mesh it with the appropriate thrust area. The realigned portion consists of three, out of seven, major goal areas: Materials Criteria, Fabrication Techniques, and Reliability. The CMS now recognizes that they pertain to both ships and offshore platforms. This commitment to offshore platforms is in itself a future thrust area and adds a second dimension to the scope of responsibility of both the MAG and LAG. The resulting portion of the realigned five-year research program is outlined below and followed in the five-year plan:

MATERIALS CRITERIA (Thrust Area 1)

Properties

- Fracture (Thrust Areas 2 and 3)
- Fatigue (Thrust Area 4)
- Corrosion (Thrust Area 5)

Applications

- Coatings
- Arctic material

FABRICATION TECHNIQUES

Welding

Underwater welding
High input heat

Inspection (Thrust Area 7)

Effects of defects (Thrust Area 6)

RELIABILITY

Inspection

Findings (Thrust Area 8)

Risk and Reliability

The five-year research planning program depicted in Table I builds on current activities and places them in perspective with contemplated work in various project areas during the next four years. The program is classified under the following seven goal areas* of the SSC:

Advanced Concepts and Long-Range Planning
Loads Criteria
Response Criteria
Materials Criteria
Fabrication Techniques
Reliability
Design Methods

*These goals were accepted and approved by the SSC in FY 1972 with the directive that all their future research plans, beginning with FY 1973, be based upon them.

TABLE I--COMMITTEE ON MARINE STRUCTURES RECOMMENDATIONS FOR THE SSC'S FIVE-YEAR RESEARCH PROGRAM

Project Area	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988
GOAL AREA: I - ADVANCED CONCEPTS AND *LONG-RANGE* PLANNING					
<u>Overall research planning studies</u>	Conduct CNS-SSSC-SNAME joint meeting to present current efforts and planned research work on offshore structures.	Conduct CNS-SSSC-SNAME joint meeting to present current efforts and planned research work on ice loads.	Conduct CNS-SSSC-SNAME joint meeting to present current efforts and planned research work in computer applications.	Conduct CNS-SSSC-SNAME joint meeting to present current efforts and planned research work on fatigue.	Conduct CNS-SSSC-SNAME joint meeting to present current efforts and planned research work on vibration or on welding defects or welding technology in terms of emerging new materials.
<u>Technical symposia</u>	<u>Continue preparations for FY 1985 Symposium Marine Structures for the Future.</u> <u>Conduct a Design-Inspection-Redundancy DIR Symposium/Workshop (SR-1299)</u>	<u>Conduct FY 1985 symposium.</u> Consider DIR Committee recommendations for follow-up symposia.	Consider topics for FY 1988 symposium.	Continue preparations for FY 1988 symposium.	Conduct FY 1988 symposium

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Key:
Underlined text refers to completed, active, and pending projects, and certain committee efforts.
"SR-0000" designation refers to projects described in the yellow pages of this report.

Open text refers to proposed projects and research efforts.
"85-00" refers to project recommendations described in the green pages of this report.

Table I--Continued

Project Area	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988
GOAL AREA: II - LOADS CRITERIA					
Static/quasi static			Develop project descriptions to conduct data collection program for still-water bending moment.	Conduct still-water bending moment data collection program.	Continue data collection program. Review first-year results.
Dynamic	Compile, review, & correlate model and full-scale liquid slosh data. Devise & conduct model tests with various fill depths, specific densities, geometrics, and excitations. (SR-1284)	Develop general-purpose curves and tables of dynamic loading data for use in design of liquid cargo tanks. (SR-1284)	Review SR-1284 data and determine if further research efforts are required.		
Wave-statistics	Compile representative data of wind and directional wave spectra joint probability of occurrence. (SR-1287)				
Extreme waves	Develop project descriptions to pursue extreme waves definition.	Develop techniques for analyzing the special characteristics of extreme waves. (85-4)	Develop extreme wave theory from fluid mechanics point of view for use in simulation and analysis.	Undertake application to novel offshore structures, green water, slamming, etc.	

Table I--Continued

Project Area	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988
		GOAL AREA: II - LOADS CRITERIA (continued)			
Extreme waves (cont'd.)		Develop test tank techniques for creating large, steep, elevated waves and wave groups having specific non-Gaussian time-domain characteristics. (85-10)	Conduct demonstrative model tests in extreme wave conditions which involve slamming and green water. (85-10)	Correlate extreme wave theory with model test data.	
Slamming and green water	Follow SNAME HS-2 Panel work on bottom slamming bow form characteristics definition. Evaluate need for full-scale slamming data.	If needed, develop detailed plan for full-scale slam instrumentation & wave-meter data collection on ocean-going ship, with due consideration for follow-on model tests.	Implement plans for full-scale slam instrumentation, and data collection on ocean-going ship.	Analyze data collected from full-scale test and compare them with theoretical results.	Examine total slamming program results to develop where additional work may be needed.
	Develop a motions and distributed loads computer program for predicting ship motions and wave loads above and below the still-water line. (SR-1277)	Develop project description to pursue predictive methods for slamming, and green water on deck.	Formulate a hydrodynamic model for predicting ship motions and wave loads under slam conditions, and green water on deck.	Develop a motions and distributed loads computer program for various sea and ship attitude conditions, including oblique encounters.	Complete computer program and evaluate oblique sea, slamming and green water on deck effects.

Table I--Continued

Project Area	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988
		GOAL AREA: II - LOADS CRITERIA (continued)			
Slamming and green water (cont'd)				Consider developing preliminary design procedures for ends of ships to avoid vibration and slamming damage.	Develop and verify the preliminary design procedure for ends of ships.
Oblique seas (non-extreme)		Compare full-scale M/V CORT pressure data for head and oblique seas. (85-12)	Evaluate results.	Accomplish model tests in oblique waves and perform model/model and model/full-scale comparisons.	Evaluate tests and data comparisons as an acceptable base for computer program verification.
Collisions and groundings	Develop specifications for calculation aids for the assessment of damage, stability, and survivability of grounded vessels. (SR-1294)	Follow USCG efforts on developing a computer program for grounded *vessels*.	Establish feasibility for model simulation of groundings according to various scenarios & associated model experiments.	Investigate interim design proposals to limit grounding damage.	
			Investigate the common technologies and engineering analysis applicable to both collision and grounding problems.	Develop analytical procedures for low energy collision & grounding including studies by structure type.	Develop generalized design guidelines for low energy absorption criteria of parametric studies for various structural configurations.
				Consider a hull structural elements model test ship collision program.	Conduct half-scale model tests.

Table I--Continued

Project Area	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988
GOAL AREA: II - LOADS CRITERIA (continued)					
Ice loads	Analyze SR-1291 data from ice breaker hull load measurements.	Collect a second year's data. (85-1)			
			Refine load factors, compare ice strengthening scantlings resulting from this approach with existing criteria, and reduce to a limited number of ice cases.	Develop response factors by applying analytic techniques to various hull configurations and ice loadings.	Generalize analytical model of ship-ice interaction to provide for high triaxial crushing strengths, high-strain rate, and irregular load distribution.
Combined loads				Evaluate utility of using ultimate strength in hull girder design roles.	
			Consider need to develop procedure for predicting transverse plane motions and transverse and torsional loads.	Develop a method to statistically estimate the combined wave-induced bending, vibration, and torsional loads necessary to perform structural failure analysis.	Prepare design load profiles & recommend modifications to design criteria.

Table I--Continued

Project Area	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988
		GOAL AREA: III - RESPONSE CRITERIA			
Nonlinear interactions	Provide a state-of-the-art review and basis for rationale for selecting strategies for performing and evaluating nonlinear analysis of marine structures under random loading. (SR-1304)	Develop project description for program to assess interrelationships and nonlinearity effects of various load conditions and failure modes in different parts of marine structure.	Assess interrelationships and nonlinearity effects of various load conditions in different parts of ship structure.	Fabricate large-scale hull girder model and test to failure, measuring stresses and deformations and comparing with calculations.	
Vibrations	Prepare a program for developing and validating hull damping calculation procedures. (SR-1307)	Examine program developed in SR-1307.	Develop a method for calculating damping in flexible hulls.	Validate calculation method with full-scale tests.	
	Develop a vibration-*control guide for ship* operators. (SR-1293)	Review guide and develop method to update, expand, and provide a more comprehensive guide.	Continue developing guide elements. Review use of vibration-control guide and update.		
	Consider developing a project *description for a* vibration design guide.	Prepare vibration-*control design* guide for structural designers of ships, introducing practical theory of vibrations, and avoiding details of *propulsion, machinery,* and mechanical systems. (85-6)	Consider extending coverage to floating platforms and offshore towers.	Develop prospectus to fill in gaps outlined in the vibration guide.	Review usage of guide and update.

Table I--Continued

Project Area	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988
		GOAL AREA: III - RESPONSE CRITERIA (continued)			
Stress and motion measurements at sea	Develop electronic ship-board strain recorder. (SR-1303)	Build, test, and validate prototype electronic strain recorder.			
	Develop a generalized operations-oriented stress and motion monitoring system. (SR-1300)	Install and operate system on three different vessel types. (SR-1300)	Evaluate results and prepare final specifications for system. (SR-1300)		
		GOAL AREA: IV - MATERIALS CRITERIA			
Properties-fracture	Develop project description to derive ship hull strain rates from existing full-scale data as suggested in the SR-1285 study.	Derive ship-board strain rates from existing stress records. Compare rates with CVN and fracture mechanics toughness tests. (85-5)	Evaluate results to determine if any change in material toughness requirements may be justified.	Consider effects of strain rates determined in 85-5 on fitness-for-service analysis. Consider necessity of evaluating effect of worst-case scenarios.	Consider reviewing fracture-design criteria in light of strain-rate studies.
	Review SR-1288 and develop project description to define a marine structural steel toughness data bank.	Initiate marine structural steel data bank project. (85-2)	Complete marine structural steel databank. (85-2) Consider efforts to close anticipated toughness data gap and to statistically evaluate toughness correlations.	Implement data gap and correlation programs if applicable. Consider small-scale test correlations for both initiation and arrest toughness.	Complete data gap and correlation program as applicable.

Table I--Continued

Project Area	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988
		GOAL AREA: IV - MATERIALS CRITERIA			
Properties-Fracture (cont'd)	Study ship fracture mechanisms in light of today's knowledge of fracture mechanics. (SR-1290)	Examine potential courses for future research and continue evaluation of new fractures. (SR-1290)	Review SR-1290 results together with those techniques of Naval Ship Research and Development Center, Annapolis, Md.	Review safety analysis of ship structural details against fracture and fatigue failures. Develop reliability-based inspection and maintenance schedules to insure safety against brittle fracture.	Develop an overall fracture-control plan for ships that incorporates both fatigue and fracture behavior of fabricated ship details and a reliability analysis.
		Review SR-1288 and develop a project description for state-of-the-art (SOTA) elastic-plastic fracture analysis for usefulness in design.	Initiate SOTA elastic-plastic fracture analysis review.	Complete review.	Incorporate results into overall fracture-control plan efforts.

Table I--Continued

Project Area	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988
GOAL AREA: IV - MATERIALS CRITERIA (continued)					
Properties-fatigue (cont'd)	Develop project description strategy for variable amplitude fatigue.	Complete SOTA review on variable amplitude fatigue. (85-9)	Review 85-9 and recommend follow-up program.	Initiate specific projects.	Continue efforts.
			Develop project description for a strategy on biaxial fatigue loading.	Complete SOTA review on biaxial fatigue loading.	Review SOTA study and recommend follow up projects.
	Evaluate SR-1276 and develop project description long-term program to develop threshold corrosion fatigue.	Initiate projects to develop test techniques. (85-8)	Obtain basic K_{th} on base metal. (85-8)	Study influence of microstructure on K_{th}.	Develop analytical design techniques.
	Determine the amount of damage produced in ship structures by cyclic loading prior to occurrence of visible cracks. (SR-1301)	Continue with fracture toughness and crack-growth rate tests on pre-fatigued ship plate. (SR-1301)	Review project results. If prior damage is detected, develop program for continued effort to quantify damage and service conditions where damage is important.	Implement research program based on any damage detected in SR-1301.	Continue program as applicable.
	Conduct fatigue tests on components and assemblies on which data are not available. (SR-1298)	Continue SR-1298.	Complete and review SR-1298.	Develop multiple-year program to evaluate effect of production deficiencies, such as weld flaws and fit up on the performance of selected structural details in fatigue.	Implement fatigue program.

Table I--Continued

Project Area	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988
		GOAL AREA: IV - MATERIALS CRITERIA (continued)			
Properties-corrosion	Define data gathering requirements and methodologies for corrosion data bank. (SR-1306)	Complete program to define data requirements. (SR-1306)	Review recommendations from SR-1306.	Implement on-going program to gather corrosion data.	Continue gathering data.
				Prepare program to develop statistical appraoch to corrosion prediction.	Initiate statistical approach to corrosion control program.
Application-coatings	Develop project description to continue development of Cu/Ni sheathing application based on review of SNAME HS-9 Project.	Continue development of Cu/Ni sheathing application based on SNAME HS-9 Project. (85-11)	Continue 85-11.	Complete 85-11 and consider application to offshore platforms in the wave zone area.	Continue as applicable.
		Consider program to determine how cathodic protection of marine structures can be optimized.	Develop project description for program, if applicable.	Initiate research as necessary.	Continue efforts.
Applications-arctic Material	Review service experience on steels in nonmarine, cold-weather applications to evaluate for potential marine use. (SR-1302)	Review SR-1302 and compare with NBS results on arctic materials research.	Undertake new material research relevant to arctic resource development based on SR-1302.	Continue research.	Continue research.

Table II--Continued

Project Area	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988
		GOAL AREA: V - FABRICATION TECHNIQUES			
Welding-underwater	Examine performance of underwater and water-backed welds. (SR-1283)	Conduct necessary testing and evaluate program. (SR-1283)	Review SR-1283 results and recommend follow-up efforts.	Initiate new projects as necessary.	Continue research.
Welding-high input HAZ	Complete study of most promising steel composition (SR-1256). Review recommendation to determine need for future work.				
Inspection-effect of defects	Obtain a better understanding of the dependence of the integrity of marine structures on weld porosity. (SR-1305)	Review SR-1305 results and recommend follow-up as necessary.			
		Develop project description to determine the influence of linear weld defects, including slag, on the basis of fracture mechanics requirements and nondestructive inspection (NDI) capabilities.	Initiate research on linear weld defect.	Complete linear weld defect study.	Review results and recommend follow-up as necessary.
				Develop prospectus to determine influence of planar weld defects, on the basis of fracture mechanics requirements and NDI capabilitities.	Continue studies where necessary.

Table I--Continued

Project Area	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988
		GOAL AREA: VI - RELIABILITY			
<u>Inspection-findings</u>	Develop project description to develop a probabilistic approach for incorporating inspection findings into future operational decisions.	Develop a probabilistic approach for incorporating inspection findings into future operational decisions.	Complete (85-7) and review. Recommend follow-up as necessary.		
<u>Risk and reliability</u>		Develop a document and conduct a tutorial seminar on reliability methods and their application to marine structures. (85-3)			
	Review the results and recommendations from the 1984 Design-Inspection-Redundancy Symposium/Workshop (SR-1299) to develop a long-range plan.	Outline SOTA research topics and draft project description in areas of: o System reliability o Redundancy o Inspection, and o Structural integrity for mobile offshore drilling units	Initiate research on system reliability, e.g.: o Failure modes o Classical reliability o Practical aspects	Continue system reliability projects.	Hold symposium to assimilate results in areas of system reliability and redundancy.

Table I--Continued

Project Area	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988
			GOAL AREAL: VI - RELIABILITY (continued)		
Risk and reliability (cont'd)			Initiate research on redundancy, e.g.: o Reserve strength o Residual strength	Continue redundancy projects on generic physical models.	
			Finalize strategy for inspection and repair research guide	Initiate research on: o Cost effective & reliable methods of inspection, o Response to detected flaws, and o Cost effective and reliable methods of repair	Develop comprehensive structural integrity guidelines* for: o Ships, o Floating marine structures, and o Fixed offshore platforms
			Pilot program to define elements of lifetime structural integrity for mobile offshore drilling units.		*Course material for educational seminars - not draft regulations.
			GOAL AREA: VII - DESIGN METHODS		
Design procedures	Examine SL-7 hatch-corner failure, and document and compare experience with theoretical calculations. (SR-1297)	Review SR-1297 results.			
Design of welded ship details	Develop a design guide for structural details that will assist designers in the selection of sound cost-effective details. (SR-1292)	Complete design guide for structural details. (SR-1292)			

FISCAL YEAR 1985 PROJECT RECOMMENDATIONS

Table II lists the projects proposed for the FY 1985 program in priority order. This list is based on the composite judgment of the CMS members who considered, among other things, the recommendations of their advisory groups; the applicability of the projects to the SSC research program in terms of needs, immediacy, program continuity, and likelihood of successful and meaningful completion, the importance of the project to marine structures; the project's potential for significant results; and that the work was not being done elsewhere. Descriptions for each of these projects follow Table II in the same priority order.

TABLE II -- RECOMMENDED PROJECTS FOR FY 1985

ICE LOADS AND SHIP REPONSE TO ICE - SECOND SEASON

CMS PRIORITY 1

Introduction

Full-scale measurements of local ice pressures were made onboard the USCG icebreaker POLAR SEA in 1982 operating in the Chukchi Sea.

Strain measurements were made on a 12-meter-square stiffened portion of hull plating in the bow region of the ship utilizing a 60-channel digital data acquisition system. Strain-gauge calibration was carried out statically using tensioning devices to laterally load the instrumented area at discrete locations on the inside of the hull. A finite-element model was used to estimate the anticipated strains based on predicted ice pressures of 20 kg/cm^2 for unconstrained crushing and 5 kg/cm^2 for flexural strength.

Field measurements were carried out in multi-year ice with thicknesses up to 15 m. Single panel pressures, as high as 110 kg/cm^2, were encountered.

The opportunity exists to gather a second year of data using the existing equipment installed onboard the POLAR SEA. The ice characteristics and grain structure are highly variable from year to year and depend on various factors including temperature and salinity. A second season of data would provide a larger data base and greatly enhance the assessment of the variability.

To ensure the quality of data generated, it would be prudent to recalibrate the strain measuring devices. This also would provide greater confidence in the data already processed since some of the pressures measured were much higher than anticipated.

Recommendation

Pursue the efforts on defining ice loads and ship response to ice by:

- Recalibrating the strain measuring devices on the POLAR SEA, and
- Gathering such data as are available next season.

MARINE STRUCTURAL STEEL TOUGHNESS DATA BANK

CMS PRIORITY 2

Introduction

A recent examination of fracture-control practices for fixed offshore structures sponsored by the SSC* draws attention to the dearth of fracture-mechanics toughness data. There is a need for measures of fracture toughness that reflect: (1) the possible flaw locations (i.e., the base plate, weldment, or HAZ), (2) the geometric features of the full-scale structure (e.g., section size, thickness), (3) service temperatures and loading rates, as well as the variations in (4) the heat-to-heat chemistry and processing, and (5) the welding conditions. The nature of the initiation event, e.g., a stationary crack versus a dynamic pop-in, must be considered. Since the minimum toughnesss requirements are normally specified in terms of CVN properties, the correlation between the CVN-values and the fracture-toughness measurements also must be defined. Much of this large body of toughness data remains to be assembled and systematized.

Recommendation

Assemble a data bank of existing fracture-toughness values for structural steels meeting marine requirements both as a convenient source of design data and as a means of identifying the data gaps by:

- Compiling "valid" or "bounding" measures of such fracture toughness parameters as K_{Ic}, K_{Ia}, J_{Ic}, COD and the R- and J- resistance curve as well as descriptions of the statistical variations of these quantities,
- Correlating between fracture-mechanics toughness values and CVN properties for individual steels and weldments, and
- Encompassing base plate, weldments, and the HAZ in thicknesses up to 10 cm.

* SR-1288, "Fracture Control for Fixed Offshore Structures," Failure Analysis Associates, Palo Alto, California.

APPLICATION OF RELIABILITY METHODS TO ANALYSIS AND DESIGN OF MARINE STRUCTURES

CMS PRIORITY 3

Introduction

Statistical techniques for characterizing stationary sea states and linear vessel response are well established in marine structural design. Recent developments in probabilistic design theory provide the mathematics for incorporating other sources of uncertainty in a framework which produces estimates of risk or probability of failure in a structure or component thereof. A reliability approach has the promise of providing better engineered designs (i.e., higher reliability and/or lower cost), but there are hazards.

There are several reasons why risk estimates should not be taken too literally: (1) There is always a question of the appropriate form of the statistical model. (2) Questions of the inadequacy of the data base will always be present. (3) The physical problem is often oversimplified to make the mathematics tractible. (4) Major sources of uncertainty are not always included in the problem. (These may include modeling errors or gross errors). (e) Errors are often introduced by linearization and approximation techniques.

In summary, reliability methods provide researchers and designers of marine structures with a powerful tool. However, there is a danger of misuse of this tool if the mathematics and hazards of risk analysis are not understood. Therefore, there is a need to provide a tutorial level summary of the state of the art in structural reliability theory directed specifically towards the marine industry.

Because this is a timely and complex subject, the tutorial text should be supplemented by a seminar. In addition to overcoming the entry threshold, which often discourages technical people from using reliability methods, presentation to an audience will help to clarify and refine the textual material.

Recommendation

Develop a document which provides a tutorial review of reliability methods, their application to marine structures, and potential pitfalls.

Present an educational seminar (1 week) for designers and researchers in the marine structures field, which like the document:

- Reviews basic theory with emphasis on marine applications, and

- Addresses caveats and shortcomings of classical theory in practical engineering applications.

Refine and publish the text as a manual for future reference in SSC-related work.

Introduction

The present methods of simulating waves in the test tank and on the computer are based on the sea surface being normally distributed. In addition, linear structural analysis schemes are well suited to such wave input information inasmuch as the output is in the same Gaussian terms. These facts mean that extensive experimental understanding, computer software, and analytical competence exist in the profession in the use of Gaussian descriptions of the wave phenomena. On the other hand, there is evidence from the report SSC-320*, and other sources, that extreme waves exist and that their occurrence and characteristics may not be predicted by the Gaussian simulations. Of even greater importance is the evidence that these extreme waves produce significant damage to vessels.

The design of fixed offshore structures already considers extreme waves having such nonlinear characteristics as elevated crests and nonlinear drag forces. If substantiated, these critical concerns can warrant extensive changes in design and simulation procedures.

Recommendation

Pursue the analysis of wave characteristics in extreme seas by:

- Developing further the techniques for identifying the special characteristics of extreme waves from storm records, and

- Developing alternative statistical or deterministic wave treatments which can be utilized expediently in testing, simulation, and analysis schemes.

* SSC-320, "A Study of Extreme Waves and Their Effects on Ship Structure," Buckley, W. H., Ship Structure Committee, 1983.

Introduction

Since the measurement of toughness of ship steels varies with strain rates, it is necessary to define the range of strain rates encountered by ships in service. This information would then allow designers to evaluate the conservatism of the steel testing techniques that are used to classify ship steel toughness.

In a recently completed feasibility study, SSC-317*, the evaluation of existing data from shipboard stress instrumentation programs indicated that it is feasible to obtain strain-rate information within the frequency limitations of the data acquisition techniques employed.

The preliminary estimates of strain rates from existing data indicate that ship service experience produced strain rates up to 10^{-3} cm/cm/sec. CVN information is based on a strain rate of 10 cm/cm/sec., and fracture-mechanics testing is at 10^{-5} cm/cm/sec. Crack initiation is of primary interest here rather than crack propagation or arrest.

The results of a thorough analysis should permit a valid evaluation of ship steel toughness of strain rates imposed by:

- o Ship service,
- o Charpy testing, and
- o Fracture mechanics testing.

These data would be useful to determine whether current toughness test requirements are conservative, and to unify service and testing based upon strain rate.

Recommendation

Confirm the preliminary ship hull strain rate estimate of 10^{-3} cm/cm/sec by:

- o Processing selected SL-7 analog and digital full-scale ship response data to obtain, analyze, and correlate these strain-rate data with ship speed, heading, loading, and encountered wave conditions, and

- o Performing probabilistic analyses to establish the distribution of strain rates for various sea states.

Introduction

Vibration imposes a serious fatigue loading on ship structures as well as introducing an objectionable environment for personnel, machinery, and equipment. A number of recently built vessels have performed well in this regard and experienced minimum vibration as a result of engineering efforts from the earliest stages of design. However, there is no guide to this procedure available in general to design offices. This design guide would set forth a rational approach to the avoidance of deleterious vibration in the design stages of new ships. It would briefly define the basics of vibration and delineate state-of-the-art procedures, information, and experience for minimizing vibration. It would also include procedures and information which are of changing nature and need further development of modification before being integrated into a state-of-the-art design procedure.

Emphasis should be placed on preliminary design and detail design of the structure vis-a-vis details of propulsion, machinery, and mechanical systems design, but point out the areas where interface to such machinery design is needed.

Recommendation

Prepare a ship vibration design guide showing the most recent techniques, procedures, and empirical rules for use by practicing naval architects and structural engineers in the design cycle.

* SSC-317, "Determination of the Range of Shipboard Strain Rates," Giannotti, J. G., and Stambaugh, K. A., Ship Structure Committee, 1982.

RELATION OF INSPECTION FINDINGS TO FATIGUE RELIABILITY

CMS PRIORITY 7

Introduction

There is an increasing trend toward ship/platform inspections, whether due to the mere spread of regulatory controls, experience with failures, increasing severity of service conditions, concern about structures extended beyond their design service lives, or all of these reasons collectively. Ship and platform operators, as well as regulatory bodies, have a keen interest in optimizing safety and economy. Inspections are expensive. Hence, there is strong incentive in using the inspection findings to the best advantage.

Design procedures have varied over the years, both in sophistication and accuracy of inputs such as environmental loadings and fatigue capacity data*. Yet, less sophistication does not necessarily mean that the structures are less safe since design procedures are not always well calibrated to actual performance. Any inspection finding, good or bad, is potentially valuable in modifying procedures for future designs. However, there are a number of logical questions regarding how to use the results for future operational decisions regarding the specific structure inspected. For example, one might ask, "What is the fatigue reliability for future service?" or, "When should the next inspection occur to have an acceptably low probability of fatigue failure in the interim?"

Answers to the above types of questions are more difficult in the instance where no evidence of cracking is found. However, even in the instance where cracks are found, there is additional uncertainty in the cause of cracking and the value of repair, but they are being repaired.

Recommendation

Develop a probabilistic approach for incorporating inspection findings into future operational decisions by:

- Synthesizing any schemes available in the literature (perhaps used by other industries),
- Updating fatigue reliability for ships and platforms in light of inspection findings, and
- Developing a reliability-based inspection intended for both ships and platforms and reflecting inspection findings.

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* SSC-318, "Fatigue Characterization of Fabricated Ship Details for Design," Munse, W. H., et al., Ship Structure Committee, 1982.

Questions to be addressed are:

- How can the probabilities be treated in the relative sense, perhaps with respect to the (implicit) initial design assumption?

- How should the potential of inspector error (related to ease of inspection) and the sensitivity of the inspection technique be taken into account?

- How does the definition of fatigue failure used make a difference?

- How should past and future loading conditions which vary from those envisioned in design be included?

- How does the extent of inspection (i.e., number of details inspected) affect the probabilistic statement for the structure as a whole?

- How can the potential of (still hidden) fabrication or installation (originated) cracks be incorporated into an assessment of future in-service performance?

THRESHOLD CORROSION FATIGUE OF WELDED MARINE STEELS

CMS PRIORITY 8

Introduction

Fatigue is one of the primary modes of failure in offshore structures. The design of offshore structures has primarily relied on classical fatigue data obtained from S-N testing. These data, combined with analysis and operating experience, have resulted in reasonably good performance. However, with more novel offshore structure designs which contain more complex load paths, the material requirements may limit the usefulness of the classical fatigue design approach. To help overcome the lack of long-term corrosion fatigue data, the SSC initiated a three-year study* directed at obtaining data on marine materials.

The information from this study, which is now being disseminated, is of value for all future designs. However, the study has indicated the need for additional basic design data. Specifically, the use of the fracture-mechanics fatigue-crack-growth analyses requires fundamental information about how materials behave in the threshold region in a marine environment. Threshold crack growth, which is in the low-growth, high-cycle, low-load regime of fatigue testing, is really of the most value for designers. This region of fatigue crack growth is analogous to endurance-limit behavior using the S-N approach to fatigue. These data are difficult to obtain in an ideal environment such as air because of the sensitivity required of the measurement techniques. Data gathering difficulty is compounded in corrosion fatigue because one has to provide accurate crack measurements for long-term periods in the corrosive environment of sea water. Therefore, a significant effort must be expended to develop methods to determine low crack-growth-rate data in sea water.

Once an experimental technique is developed, it is anticipated that various fatigue-crack-growth variables in sea water, such as temperature, oxygen content, and cathodic polarization, will be explored. This basic information must be obtained for the steels proposed for future designs. Ultimately, after the base metal crack-growth-rate characteristics are determined, studies on the weld and the weld heat-affected zone should be determined. This information will allow a more reliable design and allow accurate residual life assessments of offshore structures, both proposed and currently in use.

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* SSC Project SR-1276, "Long-Term Corrosion Fatigue of Welded Marine Steels," Southwest Research Institute.

Recommendation

Initiate determination of threshold corrosion fatigue characteristics of welded marine steels by:

- Developing test techniques having high reliability over extended test durations in a sea-water environment to obtain low growth rate fatigue-crack-growth data, and

- Demonstrating validity of test techniques by obtaining basic threshold value crack-growth data on a representative marine steel base metal, including the influence of environmental and loading variables.

FATIGUE PERFORMANCE UNDER VARIABLE AMPLITUDE LOADING

CMS PRIORITY 9

Introduction

Ships and offshore structures are often subjected to loadings which vary in amplitude over time. Yet, fatigue capacity data of plain or welded details usually come from constant amplitude tests. To use such data, whether of the fracture mechanics or S/N curve type, designers normally assume that the Palmgren-Miner (P-M) rule is valid. The rule assumes that the results are not affected by the order of variable amplitude application (i.e., no interaction). Hence, the damage or crack growth from various cycles can be treated as independent and simply summed together to determine when failure should occur.

It has long been recognized that the P-M rule can be in error, particularly when there are dramatic changes in stress amplitude from one cycle to the next. Crack growth can accelerate or retard under certain conditions. However, the question of interest with ships and offshore structures is how accurate the P-M rule is under random sea state conditions.

The aircraft industry has had an interest in random fatigue for several decades. The highway bridge people have also funded random fatigue tests since the early 1970s. Offshore-related studies are somewhat newer with some of the initial efforts being made in the United Kindom. At present, there are substantial offshore, variable amplitude test programs in the United Kingdom, United States, Germany, and Japan.

Recommendation

Develop a strategy for variable amplitude fatigue investigation by preparing a state-of-the-art review for:

- o Establishing a bibliography of worldwide references with particular emphasis on recent and ongoing work,
- o Identifying typical loading spectra,
- o Assessing the results and any disagreements, and
- o Defining a list of research needs in priority order.

The references should include analytical as well as experimental information. The environmental conditions should include air and sea water with various levels of cathodic protection. Questions to be addressed are:

- Do different materials such as steel and aluminum have similar P-M characteristics?

- Are welded details apt to perform differently than plain material?

- How are the results affected by the definition of failure?

- Is there a different answer for an initiation-dominated detail than for a propagation-dominated one?

- Is block length important in testing?

- Does clipping the extreme but rare peaks make a difference?

- What is the spectrum bandwidth at which supposedly narrow band results converge on wide band ones?

- Is it necessary to test a long-term stress history, or would the performance under one sea state be representative of most others?

- How does the fatigue limit or crack-growth threshold affect the answer?

Introduction

SSC-320, "A Study of Extreme Waves and Their Effects on Ship Structure" by W. H. Buckley, showed how extreme waves play a significant role in ship casualties. Extreme waves also influence and sometimes govern the design of offshore platforms. These waves may have nonlinear characteristics, such as elevated crests.

Recent work at the U.S. Naval Academy has demonstrated the ability to develop at least one type of episodic wave and to analyze the resulting ship motions.

Project SR-1304 is anticipated to review strategies for evaluating nonlinear analysis of marine structures under random loading, and provide a rationale for interpreting the response extremes on a consistent reliability basis.

Nonlinear response is usually associated with extreme waves, either due to velocity-squared drag forces in local loadings, or to step-wise changes associated with such events as slamming and green water on deck. These latter events, and how they combine with other wave-induced stresses, are sensitive to the particular time-series character of extreme waves and wave groups.

Recommendation

Contribute to the research regarding extreme waves by:

- Developing test strategies and criteria for evaluating the results (e.g., scaling laws), appropriate for the nonlinearities involved,
- Developing and demonstrating test tank techniques for creating large, steep, elevated waves and wave groups having specific time domain characteristics at the model, and
- Demonstrating these techniques by testing a model in conditions representing incidents of severe slamming or green water.

Introduction

The SNAME Panel HS-9 has completed an economic* analysis of applications of copper/nickel (Cu/Ni) sheathing on vessel hulls.

The results of that study show that in spite of a) high initial costs of installing Cu/Ni sheathing to an existing hull, b) higher insurance rates, and c) higher repair costs, the freight rate for Cu/Ni sheathed vessels is substantially lower than for two other hull protective coating systems. The SNAME panel reported that because of the superior antifouling quality of Cu/Ni sheathing, hull resistance did not increase during the lifetime of the vessel and therefore no speed loss was experienced; or conversely, no increase in shaft horsepower (fuel consumption) was required to maintain speed. Also, less frequent drydocking was required.

Recommendation

Pursue the application of this material by:

- Evaluating nondestructive examination methods for welds in Cu/Ni sheathed hulls. Panel-to-panel and panel-to-hull welds should be considered. In addition, hull welds beneath Cu/Ni sheathing panels and hull thickness gaging should be addressed.

- Evaluating the effects of weld discontinuities in panel-to-panel and panel-to-hull welds. In addition, evaluate consequences of nondiscovery of weld discontinuities in hull welds beneath Cu/Ni panels.

- Evaluating the effects of pinholes or defects in the Cu/Ni sheath panels, including detection and corrosion rates.

* "Cu/Ni Sheathing of Ship Hulls: Technology and Economy," SNAME, March 1983.

COMPARE PRESSURE DISTRIBUTION MEASUREMENTS IN OBLIQUE AND HEAD SEAS

CMS PRIORITY 12

Introduction

Full-scale pressure distribution measurements have been made on the M/V CORT in both head and oblique seas. Whether or not hull pressures are more critical in the head sea or oblique sea condition is important in the assessment of hull loads and germane to the pursuit of model testing programs and computer simulation programs. The present, but temporary, existence of a model of the M/V CORT suggests that a comparison of these measurements be made promptly to assess the importance of conducting oblique wave model tests.

While many SSC programs deal primarily with sea loads imposed on the hull girder, knowledge of pressures on the hull surface is also needed to determine the required strength of local structures to withstand maximum anticipated pressures at sea. Three recent projects, two by SSC and one by ABS, have been concerned with model, full-scale, and computed results of the Great Lakes self-unloader STEWART J. CORT, and, model and computed results for the SL-7 class containership SEALAND McLEAN.

Models for both vessels were tested in head seas only for a variety of speeds and wave lengths to measure pressures at various locations over the hull and to measure the separate components of pressure. Full-scale pressure measurements for the STEWART J. CORT not only included head sea conditions, but 13 data runs at a 45° heading to the waves, three in beam seas, and four in the following seas.

The ABS compared their ship-motion computer program results with selected head-sea run conditions, and concluded that the correlation of theoretical calculations of motion and pressures with both model-test and full-scale measurements is very encouraging. However, further correlation with oblique sea running conditions can not be made until the computer program is expanded to accommodate oblique sea conditions.

Recommendation

Establish whether hull pressures are more critical in the head sea or oblique sea conditions by:

- Using the existing full-scale test results for the M/V CORT, compare head wave with oblique wave performance,

- Determining the relative criticality of head seas versus oblique seas on hull pressures based on these full-scale test results, and

- Recommending whether or not future model tests in oblique seas would be desirable.

REVIEW OF ACTIVE AND PENDING PROJECTS

This section of the report covers current projects funded with FY 1983 (or earlier) funds, others that have been continued with FY 1984 funds, and those which are anticipated to be supported with FY 1984 funds. These projects, listed in Table III, constitute the current program. The majority of projects are for one year's duration; multiyear projects are funded incrementally on an annual basis.

Project descriptions, including the project number and title, the name of the principal investigator and organization (where determined), and a brief statement of the objective of each project is given. These are followed by a short description of the present status of the project.

TABLE III -- REVIEW OF ACTIVE AND PENDING PROJECTS

PROJECT NO: SR-1277
PROJECT TITLE: ADVANCED METHOD FOR SHIP MOTION AND WAVE-LOAD PREDICTIONS
INVESTIGATOR: Mr. J. C. Oliver
CONTRACTOR: Giannotti and Associates, Inc., Annapolis, MD

OBJECTIVE

The objective of the study is to develop a method and appropriate computer program for predicting ship motions and distributed wave loads, taking into account the hull form shape above and below the still water line, including the three-dimensional hydrodynamic coefficients.

STATUS

A draft final report has been revised and is being reviewed. The suggested title for the report is, "A Time-Domain Method for Ship Motion and Wave-Load Prediction."

TECHNICAL ADVISORS

Dr. O. H. Oakley, Jr., Gulf Research & Development Company, Houston, TX
Prof. N. A. Hamlin, Webb Institute of Naval Architecture, Glen Cove, NY
Prof. W. H. C. Maxwell, University of Illinois, Urbana, IL
Dr. W. R. Porter, State University of New York, Maritime College, Bronx, NY

PROJECT NO: SR-1283
PROJECT TITLE: PERFORMANCE OF UNDERWATER WELDMENTS
INVESTIGATOR: Mr. E. B. Norris
CONTRACTOR: Southwest Research Institute, San Antonio, TX

OBJECTIVE

The objectives of the proposed research are to gather data on the mechanical properties of wet and wet-backed underwater weldments and to provide guidelines relating these properties to design performance.

STATUS

Mechanical testing is proceeding on 19 ferritic grooved weld specimens, 3 fillet weld specimens, and the 3 all-welded specimens, using 0.36 (with ferritic electrode) and 0.46 (with austinetic electrode) carbon-equivalent steel plate in half and one-inch thicknesses, for the 0- and 9.9-meter depths. Presently, the 19 groove welds have successfully passed the transverse weld tensile test, but five have had some problems in passing the 6T (6 plate thicknesses) bend test. Problems have been encountered with the fabrication of wet welds using a nickel alloy filler rod at depths of 19.8 and 29.7 meters.

TECHNICAL ADVISORS

Prof. D. L. Olson, Colorado School of Mines, Golden, CO
Mr. C. E. Grubbs, D&W Underwater Welding Services, Inc., Slaughter, LA
Dr. S. Ibarra, Gulf Science & Technology Company, Pittsburgh, PA
Mr. E. L. Von Rosenberg, Exxon Production Research Company, Houston, TX

PROJECT NO: SR-1284
PROJECT TITLE: LIQUID SLOSH LOADING IN CARGO TANKS
INVESTIGATOR: Prof. N. A. Hamlin
CONTRACTOR: Webb Institute of Naval Architecture, Glen Cove, NY

OBJECTIVE

The objective of this study is to determine sloshing loads on the boundaries, swash bulkheads, and internal framing of partially filled tanks of various proportions for liquids of specific gravities ranging from 0.4 to 1.8 and typical enroute service viscosities.

STATUS

A phase I report is being drafted that will summarize the survey of full-scale experience and cases where sloshing has been a problem with internally stiffened tanks, as well as the characteristics of liquid cargo carried. Two typical ship designs will be recommended as representing ships with internally stiffened tanks which may have problems from sloshing, and the details of the tank internal structure will be described. More important will be the description of the test program to be considered before commencing with phase II.

TECHNICAL ADVISORS

Mr. C. W. Coward, Newport News Shipbuilding and Dry Dock Company, Newport News, VA
Prof. R. F. Beck, University of Michigan, Ann Arbor, MI
Dr. J. P. Hackett, Ingalls Shipbuilding, Pascagoula, MS

PROJECT NO: SR-1287
PROJECT TITLE: JOINT OCCURRENCE OF ENVIRONMENTAL DISTURBANCES
INVESTIGATOR: Mrs. S. L. Bales
CONTRACTOR: David Taylor Naval Ship Research and Development Center, Carderock, MD

OBJECTIVE

The objective is to develop a method and a representative data bank, useful for design, that identifies the simultaneous occurrence of winds and directional wave spectra.

STATUS

A draft final report is being prepared.

TECHNICAL ADVISORS

Prof. M. K. Ochi, University of Florida, Gainesville, FL
Dr. D. Hoffman, Hoffman Maritime Consultants, Glen Head, NY
Dr. O. H. Oakley, Jr., Gulf Research & Development Company, Houston, TX
Mr. David Price, National Oceanic and Atmospheric Administration, Rockville, MD

PROJECT NO: SR-1290
PROJECT TITLE: SHIP FRACTURE MECHANISMS INVESTIGATION
INVESTIGATOR: Dr. J. G. Giannotti
CONTRACTOR: Giannotti & Associates, Inc., Annapolis, MD

OBJECTIVE

The objectives of this study are to examine current and future ship fractures over a period of years, to examine past ship fractures in the light of present understanding, and to catalog and assess the types of fractures that occur in ship structures.

STATUS

A literature review is nearing completion while simultaneous efforts are being put forth to obtain failure experience service data from ship owners, ship operators, and ship repair yards. The majority of ship operators contacted do not analyze the ship fractures in technical terms; their main concerns have been primarily on quick repair of fractures to minimize time out of service. A checklist to aid in preparations for the examination of future fractures includes information such as required contacts for access, equipment required for the examination, and the information to obtain from the examination. This document is in letter form to send to ship owners and ship repair yards, at their request, to inform them of their possible involvement in the investigation.

TECHNICAL ADVISORS

Dr. E. J. Ripling, Materials Research Lab, Inc., Glenwood, IL
Dr. Richard Bicicchi, Sun Refinery and Marketing Company, Marcus Hook, PA

PROJECT NO: SR-1291
PROJECT TITLE: ICE LOADS AND SHIP RESPONSE TO ICE
INVESTIGATOR: Mr. J. W. St. John
CONTRACTOR: ARCTEC, Incorporated, Columbia, MD

OBJECTIVE

The objective of this project is to measure ice pressure through the measurement of structural deflections of selected portions of the hull plating on the U.S. Coast Guard icebreaker POLAR SEA to develop ice load and response criteria for various types of ice.

STATUS

The 1982 winter season of full-scale ship performance data, and ice pressures recorded on an instrumented panel, 390 cm long by 320 cm high, located in a forward ballast tank on the port side of the U.S. Coast Guard ice breaker POLAR SEA, are being analyzed and correlated with finite-element program results. In the meanwhile, the opportunity exists to gather a second season of data that would provide a larger data base for assessment of the variability of sea ice conditions. A recommendation to continue gathering these full-scale data is contained in this report as recommendation 85-1.

TECHNICAL ADVISORS

Dr. J. E. Goldberg, Lafayette, IN
Prof. C. B. Brown, University of Washington, Seattle, WA
Dr. J. G. Giannotti, Giannotti & Associates, Inc., Annapolis, MD
Prof. J. P. Murtha, University of Illinois, Urbana, IL

PROJECT NO: SR-1292
PROJECT TITLE: SHIP STRUCTURAL DETAIL DESIGN GUIDE
INVESTIGATOR: Mr. C. R. Jordan
CONTRACTOR: Newport News Shipbuilding and Dry Dock Company, Newport News, VA

OBJECTIVE

The objective of this study is to develop a design guide for structural details that will assist designers in the selection of sound, cost-effective details.

STATUS

Service experience data have come primarily from SSC reports from which an analysis indicates 6,856 failures occurred among 607,584 details for a rate of 1.13 percent. Of these fractures, 4,050 involved cracking and the remainder buckling. The most interesting result is that naval ships had a failure rate of only 0.14 percent, almost an order of magnitude less. Fabrication man-hours will be determined for a number of the details to aid the designer in selecting the most cost-effective details. The above failures occurred in 634 different configurations that were assigned to 56 family groups and 12 families. Eventually, these families will be examined and diagrams developed to ensure the designer that the elements selected reflect all possible failure modes of the actual structure.

TECHNICAL ADVISORS

Mr. O. H. Oakley, Consultant, McLean, VA
Dr. John Christodoulides, John J. McMullen, Arlington, VA
Mr. R. R. Kraft, Jr., Bethlehem Steel Corporation, Beaumont, TX

PROJECT NO: SR-1293
PROJECT TITLE: GUIDE FOR SHIPBOARD VIBRATION CONTROL
INVESTIGATOR: Mr. E. F. Noonan
CONTRACTOR: NKF Engineering Associates, Inc., Vienna, VA

OBJECTIVE

The objective of this project is to develop a vibration-control guide which will serve as a useful tool in the hands of ship operators, shipyards, and others who must deal with ship vibration problems but who have limited knowledge and experience in the field.

STATUS

Work is progressing on drafting the chapters for the following guide outline:

Introduction
Terms, Definitions, Vibration Fundamentals
Introduction to Ship Vibration - Excitation and Response
Scope and Field of Application
Reference Documents
Methods of Measuring and Reporting Shipboard Vibration
Criteria of Acceptable Levels of Vibration
Vibration Evaluation - Corrective Action
Typical Examples

The title will be "A Practical Guide for Shipboard Vibration Control and Attenuation."

TECHNICAL ADVISORS

Dr. B. L. Silverstein, Tracor-Hydronautics, Laurel, MD
Mr. R. A. Babcock, General Dynamics, Quincy, MA

PROJECT NO: SR-1297

PROJECT TITLE: FATIGUE PREDICTION ANALYSIS VALIDATION FROM THE SL-7 HATCH-CORNER STRAIN DATA

INVESTIGATOR: Drs. Y. K. Chen and J. W. Chiou

CONTRACTOR: American Bureau of Shipping, New York, NY

OBJECTIVE

The objective of this project is to compare SL-7 hatch-corner fatigue cracking experience with theoretical fatigue calculations.

STATUS

Considerable time and effort was devoted to verify data since about two-thirds were for wrong gages, and others had incorrect calibration factors supplied. Further, only 1,762 recorded intervals instead of 2,600 were useable because some of the intervals recorded on the SEALAND McLEAN did not have the original calibration factors on the analog tapes and other intervals did not have the corresponding sea state numbers indicated in the log book. Work is now proceeding to reduce the data and present the results.

TECHNICAL ADVISORS

Mr. J. E. Steele, Consultant, Quakertown, PA
Mr. J. W. Boylston, Giannotti & Associates, Inc., Annapolis, MD
Prof. H. W. Liu, Syracuse University, Syracuse, NY
Prof. W. H. Munse, University of Illinois, Urbana, IL

PROJECT NO: SR-1298
PROJECT TITLE: FATIGUE CHARACTERIZATION OF FABRICATED SHIP DETAILS -- PHASE II
INVESTIGATOR: Unknown
CONTRACTOR: Unknown

OBJECTIVE

The objective of this project is to examine, analyze, and test more structural details and determine their influence on fatigue, which will ultimately lead to analytical procedures to evaluate and select fabricated ship details.

STATUS

Proposals have been evaluated and contract negotiations are underway.

*****

PROJECT NO: SR-1300
PROJECT TITLE: DEVELOPMENT OF A GENERALIZED ONBOARD RESPONSE MONITORING SYSTEM
INVESTIGATOR: Unknown
CONTRACTOR: Unknown

OBJECTIVE

The objectives of this project are to develop a generalized operations-oriented stress and motion monitoring system, and implement it on board three different types of vessels.

STATUS

A proposal request is being prepared.

*****

PROJECT NO: SR-1301
PROJECT TITLE: STRUCTURAL BEHAVIOR AFTER FATIGUE
INVESTIGATOR: Unknown
CONTRACTOR: Unknown

OBJECTIVE

The objective of this study is to determine whether or not fatigue damage is produced in ship plates by cyclic loading below yield strengths prior to the occurrence of readily visible cracks.

STATUS

A proposal request is being prepared.

PROJECT NO: SR-1302
PROJECT TITLE: STEELS FOR MARINE STRUCTURES IN ARCTIC ENVIRONMENTS
INVESTIGATOR: Mr. R. E. Johnson
CONTRACTOR: David Taylor Naval Ship Research and Development Center, Carderock, MD

OBJECTIVE

The objective of this project is to review the service experience on steel usage in nonmarine cold weather applications to evaluate the usefulness of these steels for marine structures in an arctic environment.

STATUS

Efforts have begun to initiate a survey, review literature, and evaluate reports and service experiences, including limitation caveats, for steels employed or designated for use in arctic structures. The following topics are among those being considered in this effort: purchase specifications; actual mechanical properties and thicknesses with particular emphasis on fracture and fatigue; environmental conditions; fabrication procedures; criteria for existing configurations and loading of structures; and inspection and maintenance schedules.

TECHNICAL ADVISOR

Mr. Robert E. Somers, Welding Consultant, Hellertown, PA

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PROJECT NO: SR-1303
PROJECT TITLE: DEVELOPMENT OF AN ONBOARD STRAIN RECORDER
INVESTIGATOR: Unknown
CONTRACTOR: Unknown

OBJECTIVE

The objective of this project is to develop a self-contained onboard strain processing and recording instrument that will make use of state-of-the-art electronics to provide more useful engineering data than has been possible in the past.

STATUS

A proposal request is being prepared.

PROJECT NO: SR-1304
PROJECT TITLE: STRATEGIES FOR NONLINEAR ANALYSIS OF MARINE STRUCTURES AND CRITERIA FOR EVALUATING THE RESULTS
INVESTIGATOR: Unknown
CONTRACTOR: Unknown

OBJECTIVE

The objective of this project is to review the available strategies for performing and evaluating nonlinear analysis of marine structures under random loading and provide a rationale for selecting among them with particular emphasis on how to interpret the response extremes on a consistent reliability basis.

STATUS

A proposal request is being prepared.

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PROJECT NO: SR-1305
PROJECT TITLE: INFLUENCE OF WELD POROSITY ON THE INTEGRITY OF MARINE STRUCTURES

INVESTIGATOR: Unknown
CONTRACTOR: Unknown

OBJECTIVE

The objective of this project is to obtain a better understanding of the dependence of the integrity of marine structures on weld porosity.

STATUS

A proposal request is being prepared.

PROJECT NO: SR-1306
PROJECT TITLE: CORROSION EXPERIENCE DATA REQUIREMENTS
INVESTIGATOR: Unknown
CONTRACTOR: Unknown

OBJECTIVE

The objectives of this project are to define corrosion data requirements and data gathering methodology for a new survey upon which to eventually base a more rational approach for corrosion margins.

STATUS

A proposal request is being prepared.

*****

PROJECT NO: SR-1307
PROJECT TITLE: HYDRODYNAMIC HULL DAMPING - PHASE I
INVESTIGATOR: Unknown
CONTRACTOR: Unknown

OBJECTIVE

The objective of this project is to prepare a program for the development and validation of procedures for estimating the longitudinal distribution of energy dissipation (damping) associated with the principal flexural or "beam" modes of ship hull vibration.

STATUS

A proposal request is being prepared.

REVIEW OF COMPLETED PROJECTS

The projects completed since the last annual report are listed below. Project descriptions similar to those for the active program follow. Reports from these projects (except for SR-1295) have either been published or are in publication. The final SSC reports can be expected in the near future and will be available from the National Technical Information Service, Springfield, Virginia 22314.

PROJECT NO:	SR-1256
PROJECT TITLE:	INVESTIGATION OF STEELS FOR IMPROVED WELDABILITY IN SHIP CONSTRUCTION
INVESTIGATOR:	Dr. L. F. Porter
CONTRACTOR:	U.S. Steel Corporation, Monroeville, PA

OBJECTIVE

The objective of this multi-year study is to select the optimum materials and welding parameters to improve resistance to degradation of the heat-affected-zone (HAZ) properties in weldments made with high-deposition rate processes.

RESULTS

A steel containing (by weight percent) 0.10 to 0.12 carbon, 1.3 to 1.6 manganese, 0.3 silicon, 0.03 aluminum, 0.006 to 0.015 titanium with low sulpher (<0.005), nitrogen (<0.006), and residuals (copper + nickel + chromium + molybdynum <0.1) has shown excellent toughness in the HAZ of high-heat-input welds (400 kilojoules per cm electro slag welding) (with high CVN energy >70 joules at $-17^{o}C$), and an average base plate yield strength of 280 to 340 mega Pascals. Additional strengthening can be achieved without loss of HAZ toughness by control rolling and accelerated cooling.

TECHNICAL ADVISORS

Dr. H. I. McHenry, National Bureau of Standards, Boulder, CO
Prof. T. W. Eagar, Massachusetts Institute of Technology, Cambridge, MA
Dr. M. Korchynsky, Union Carbide Corporation, Pittsburgh, PA
Dr. J. L. Mihelich, Climax Molybdenum Company, Ann Arbor, MI
Dr. J. C. Baker, Bethlehem Steel Corporation, Bethlehem, PA
Prof. D. L. Olson, Colorado School of Mines, Golden, CO

PROJECT NO: SR-1276

PROJECT TITLE: LONG-TERM CORROSION FATIGUE OF WELDED MARINE STEELS

INVESTIGATOR: Dr. O. H. Burnside

CONTRACTOR: Southwest Research Institute, San Antonio, TX

OBJECTIVE

The objective of the research is to define and evaluate available technology for assessing the long-term corrosion fatigue behavior of welded joints in sea water, and to develop a plan for long-term future efforts, if required.

RESULTS

Mathematical models were formulated which quantified the important environmental and loading variables on fatigue crack initiation and propagation in the high- and low-cycle life regimes. The initiation model utilized the local stress-strain approach with a modified Neuber rule. The propagation model used fracture mechanics with the stress-intensity factor computed using the Green's function approach and the uncracked stress state at the toe of the weld. A three-component crack-growth equation was used to relate crack propagation to stress-intensity-factor changes in the three commonly observed regimes of growth. Both the initiation and growth models included the effects of weld toe geometry, joint geometry, plate thickness, and mode of loading. In addition, broad areas of research have been identified which would allow more reliable design and residual-life assessments of marine structures to be made.

TECHNICAL ADVISORS

Mr. P. W. Marshall, Shell Oil Company, Houston, TX
Dr. R. D. Glasfeld, General Dynamics, Quincy, MA
Prof. P. H. Wirsching, University of Arizona, Tucson, AZ

PROJECT NO: SR-1288
PROJECT TITLE: FRACTURE CONTROL FOR FIXED OFFSHORE STRUCTURES
INVESTIGATOR: Dr. Jerrell M. Thomas
CONTRACTOR: Failure Analysis Associates, Palo Alto, CA

OBJECTIVE

The objective of this study is to examine critically the technology and practices that constitute the fracture-control plans used by designers, builders, and operators of fixed offshore structures.

RESULTS

The elements of fracture control were identified as materials, design, construction, operation, and inspection. Cost-effective improvements with use of existing technology and promising areas of technical research have been identified. The survey also revealed that the more advanced fracture-control methods used in the U.S. offshore industry closely parallel those used by other high-technology industries such as aerospace, and, in some cases, sophistication of the best methods used considerably surpasses analysis requirements of typical codes used in several other industries (e.g., nuclear power). A fracture-control checklist is now available as an example of an unstructured, yet responsive, fracture-control plan.

TECHNICAL ADVISORS

Mr. D. A. Sarno, ARMCO Inc., Middletown, OH
Dr. J. D. Burke, Shell Oil Company, Houston, TX
Prof. S. T. Rolfe, Univesity of Kansas, Lawrence, KS
Dr. C. P. Royer, Exxon Production Research Company, Houston, TX
Dr. A. K. Shoemaker, U.S. Steel Corporation, Monroeville, PA

PROJECT NO: SR-1289
PROJECT TITLE: STRUCTURAL INSPECTION GUIDELINES
INVESTIGATOR: Mr. N. S. Basar
CONTRACTOR: M. Rosenblatt & Son, Inc., New York, NY

OBJECTIVE

The objective of this study is to develop a guide that will set forth a coherent philosophy toward structural inspection for marine people involved in designing, building, accepting, and operating ships.

RESULTS

An inspection guide, with documented support, has been prepared for ship structures from the initiation of the design process to the end of the vessel's useful service life. It contains, among other topics, basic design considerations that affect structural integrity of ships; methods and procedures for conducting structural inspections during construction of the vessel and during its service life; recommended recording, reporting, and analysis techniques for evaluating inspection results; references to tolerances and acceptable levels for misalignment of various structures; and recommended corrective action for typical deficiencies or deviations.

TECHNICAL ADVISORS

Mr. C. B. Walburn, Bethlehem Steel Corporation, Sparrows Point, MD
Dr. C. M. Fortunko, National Bureau of Standards, Boulder, CO
Mr. P. W. Marshall, Shell Oil Company, Houston, TX

PROJECT NO: SR-1294

PROJECT TITLE: CALCULATION AIDS FOR PREDICTING GROUNDED SHIP RESPONSES

INVESTIGATOR: Mr. J. D. Porricelli

CONTRACTOR: Engineering Computer Optecnomics, Inc., Annapolis, MD

OBJECTIVE

The objective of this project is the development of specifications for calculation aids for the assessment of damage, stability, and survivability of grounded vessels.

RESULTS

Various analytical techniques have been developed and can be accommodated within any number of existing portable computers with self-contained sources of power. Basic hydrostatic data can be determined from minimal ship data for the full load condition and at ship drafts which vary significantly from that for the full load condition at a level of acceptable accuracy for salvage purposes. While these aids will provide better insight to the nature of the problem and strengthen the development of a salvage strategy, they are not a substitute for knowledge and experience in marine salvage.

TECHNICAL ADVISORS

Prof. R. G. Davis, Texas A&M University, Galveston, TX
Mr. R. Frederick, SMIT American Salvage, Inc., New York, NY
Mr. R. V. Danielson, Timonium, MD
Capt. H. J. Spicer, Mobil Shipping and Transportation, New York, NY

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PROJECT NO: SR-1295

PROJECT TITLE: FULL-SCALE SLAM INSTRUMENTATION AND WAVEMETER DATA COLLECTION

INVESTIGATOR: Unknown

CONTRACTOR: Unknown

OBJECTIVE

The objective of this project is to instrument a particular vessel with the intent to correlate the recorded slam data with model and analytical predictions for this particular vessel.

STATUS

Proposals were evaluated, but their costs far exceeded available funding, and the project has been canceled.

PROJECT NO: SR-1299
PROJECT TITLE: DESIGN-INSPECTION-REDUNDANCY SYMPOSIUM/WORKSHOP
INVESTIGATOR: SR-1299 Steering Committee
CONTRACTOR: National Academy of Sciences, Washington, DC

OBJECTIVE

The objectives of this symposium/workshop are to examine the emerging technologies of ultimate strength and failure mode analyses as applicable to marine structure systems, to delineate the most pressing problems, and to develop a detailed work plan.

RESULTS

A three-day symposium followed by a two-day workshop was held in Williamsburg, Virginia, November 14-18, 1983. The symposium consisted of the formal presentation of 23 invited technical papers; all presentations were followed by discussions, some of which were extensive.

Two stages of research workshop sessions were organized; the first stage consisted of five groups organized following the last five sessions of the symposium, whereas the second stage consisted of three working groups along three disciplinary areas. In both stages, suggestions and recommendations for research were developed and reported by each working group. On the basis of the working groups' suggestions, the Steering Committee has formulated and developed its set of recommendations.

STEERING COMMITTEE

Prof. A. H-S. Ang, Chairman, University of Illinois, Urbana, IL
Prof. Douglas Faulkner, The University of Glasgow, Glasgow, Scotland
Mr. P. W. Marshall, Shell Oil Company, Houston, TX
Prof. Robert Plunkett, University of Minnesota, Minneapolis, MN
Prof. Masanobu Shinozuka, Columbia University, New York, NY

APPENDIX
ORGANIZATIONAL AND ADMINISTRATIVE MATTERS

Establishment of Committees

Since 1946, the National Research Council's Committee on Marine Structures (CMS) and its predecessors have been rendering technical services to the interagency Ship Structure Committee (SSC) in developing a continuing research program, sponsored by the SSC and funded collectively by its member agencies, to determine how marine structures can be improved for greater safety and better performance without adverse economic effect.

The SSC was established in 1946 upon recommendation of a Board of Investigation, convened by order of the Secretary of the Navy, to inquire into the design and methods of construction of welded steel merchant vessels. As that investigation was brought to a close, several unfinished studies and a list of worthy items for future investigation remained. The Board of Investigation recommended that a continuing organization be established to formulate and coordinate research in matters pertaining to ship structure. Figure 1 shows the relationship of the various organizational entities involved in the work of the SSC.

Membership and Responsibilities

The SSC, composed of one senior official from each of the following organizations: the U.S. Coast Guard, the Naval Sea Systems Command, the Maritime Administration, the American Bureau of Shipping, the Military Sealift Command, and the Minerals Management Service, formulates policy, approves program plans, and provides financial support through its member agencies for the research program.

The Ship Structure Subcommittee (SSSC), composed of a maximum of four representatives from each agency, meet periodically to assure achievement of program goals and to evaluate the results of research projects in terms of structural design, inspection, construction, and operation.

The CMS and its two advisory groups, the Materials Advisory Group (MAG) and the Loads Advisory Group (LAG), are composed of selected members from academic, governmental, and industrial sources for their competence and experience in relevant areas. They serve as individuals contributing personal knowledge and judgment, and not as representatives of organizations where they are employed or with which they are associated. Their responsibilities are to provide technical planning, review, and advisory relationships on the SSC's research program covering the general fields of materials, loading, response, design, fabrication, and inspection as related to marine structures.

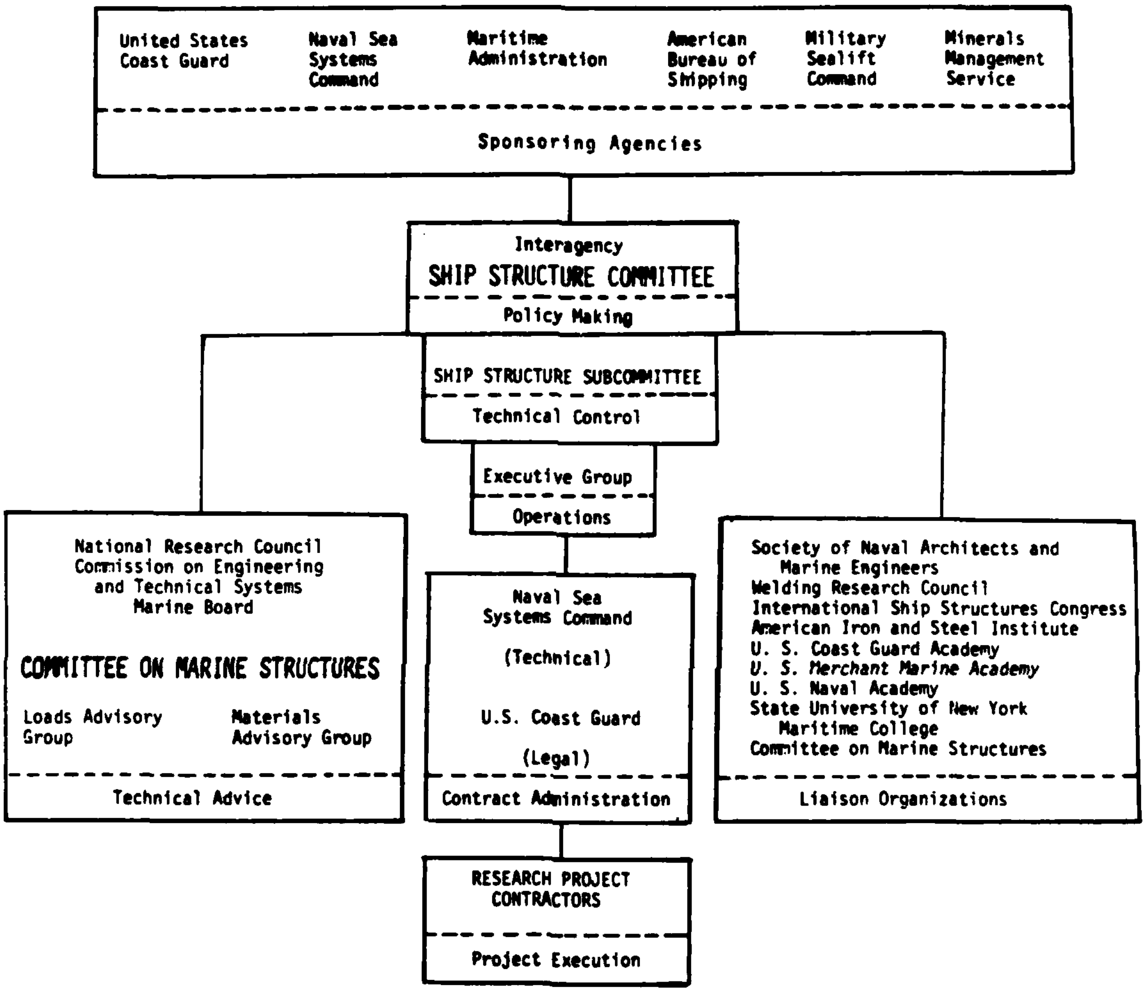


FIGURE 1. SHIP STRUCTURE COMMITTEE ORGANIZATION CHART

Research Program Development

Each organization represented on the SSC annually presents its perceived needs for near-term and long-range research efforts.

Beginning in 1976, an annual joint meeting of members of the CMS, the cognizant committees of the Society of Naval Architects and Marine Engineers, and the SSSC has been held to review these suggestions.

At a subsequent meeting, the CMS carefully considers these suggestions, those generated within the CMS and its advisory groups, those not funded from the prior year, and those obtained from any other sources.

At the fall meeting of the SSC, the CMS presents its considerations of the above suggestions and obtains the degree of mutual interest of the member agencies.

Project Development

The CMS advisory groups convene to review in detail the status of the ongoing projects, the CMS suggestions for new work, and the five-year research program plan. Then, members, either individually or in small task forces, prepare the initial descriptions of projects to be recommended.

A second meeting is convened for each advisory group to review the draft descriptions of the recommended new work, place them in a priority order, and develop the five-year research program in its respective area of competence. Each group also prepares a brief overview of the technical scope of its portion of the program, and reviews and puts in final form drafts of the status reports on active, pending, and completed projects.

The CMS receives these documents and finalizes, as necessary, all work and ranks projects for the preparation of this annual report.

The SSC determines which projects will be supported.

Project Initiation and Review

Requests for Proposals (RFPs) are prepared and issued through the cooperative effort of the Naval Sea Systems Command, which provides technical contract administrative support services, and the U.S. Coast Guard (USCG), which handles the actual business of contracting. The RFPs are sent to research laboratories, universities, shipyards, and other organizations and are advertised in the Commerce Business Daily. Organizations interested in doing the work advertised submit proposals and cost estimates to the USCG contracting office.

The SSSC appoints a Project Technical Committee (PTC) to evaluate proposals and monitor the project. This committee generally consists of individuals from the SSSC, SSSC liaisons, or other agency personnel. In addition, the CMS chairman engages one or two members from the cognizant advisory group, the CMS, or other experts in the

field as technical advisors to provide clarification on technical issues and to maintain CMS' current awareness.

The SSSC sends its proposal evaluation recommendations to the USCG contracting officer, who, following routine procurement practices, then awards a contract.

After a contract has been awarded, the PTC meets periodically with the contractor (investigator) to review the project status.

Dissemination of SSC Research Information

The contractors prepare reports upon completion of a coherent series of tests or discrete unit of work, upon a major change of course in a project, upon a significant discovery, or upon termination of a project, that are reviewed by the PTC. Normally, the SSC publishes such reports to fulfill its mission of disseminating the results of research pertaining to marine structures. In addition, the SSC encourages the investigators to prepare papers for presentation before professional society meetings or for submission to technical journals.

To foster the use of the published information, the SSC distributes the reports to individuals and agencies associated with and interested in its work. The availability of these reports is also noted by the National Technical Information Service (NTIS) and in various marine and naval architecture journals. Further, over 100 leaders and officers of the marine structure community receive personal copies directly from the SSC chairman.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
	AD-A139 802	

4. Title and Subtitle	5. Report Date
RECOMMENDATIONS FOR THE INTERAGENCY SHIP STRUCTURE COMMITTEE'S FISCAL 1985 RESEARCH PROGRAM	1984
	6. Performing Organization Code
	8. Performing Organization Report No.
7. Author(s) COMMITTEE ON MARINE STRUCTURES	
9. Performing Organization Name and Address NATIONAL RESEARCH COUNCIL 2101 CONSTITUTION AVENUE WASHINGTON, D.C. 20418	10. Work Unit No. (TRAIS) 11. Contract or Grant No. DTCG23-84-C-20005
12. Sponsoring Agency Name and Address COMMANDANT (G-DSI) U.S.COAST GUARD HEADQUARTERS OFFICE OF RESEARCH AND DEVELOPMENT WASHINGTON, D.C. 20593	13. Type of Report and Period Covered 14. Sponsoring Agency Code

15. Supplementary Notes

The USCG acts as the contracting office for the Ship Structure Committee

16. Abstract

The Committee on Marine Structures (CMS) of the Marine Board of the National Research Council provides technical services covering planning, review, and advisory relationships to the interagency Ship Structure Committee (SSC), composed of representatives from the U.S. Coast Guard, the Naval Sea Systems Command, the Maritime Administration, the American Bureau of Shipping, the Military Sealift Command, and the Minerals Management Service. This arrangement requires continuing interaction between the CMS and the SSC to assure an effective program to extend knowledge of materials, loading, response, design, fabrication, and inspection as related to marine structures. This report contains the CMS' recommended research program for five years, fiscal years 1984-1988; 12 project descriptions for fiscal year 1985; and a brief review of 18 active and six recently completed projects.

17. Key Words	18. Distribution Statement
	This document is available to the public through the National Technical Information Service, Springfield, VA 22161

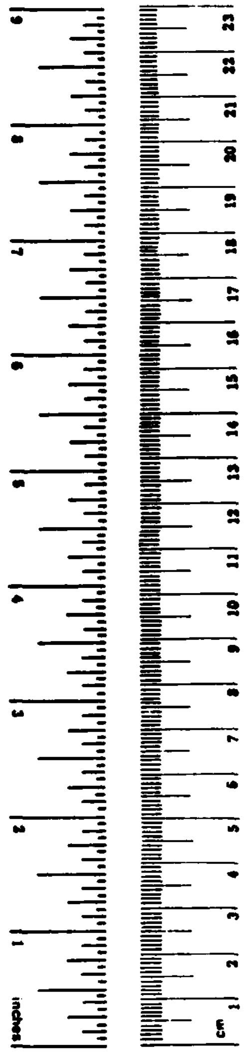
19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED	66	

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

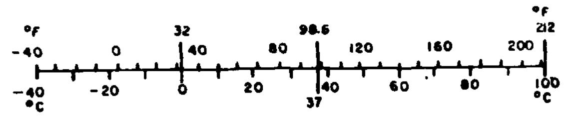
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



THE NATIONAL ACADEMY OF SCIENCES is a private, honorary organization of more than 900 scientists and engineers elected on the basis of outstanding contributions to knowledge. Established by a Congressional Act of Incorporation signed by Abraham Lincoln on March 3, 1863, and supported by private and public funds, the Academy works to further science and its use for the general welfare by bringing together the most qualified individuals to deal with scientific and technological problems of broad significance.

Under the terms of its Congressional charter, the Academy is also called upon to act as an official - yet independent - advisor to the Federal Government in any matter of science and technology. This provision accounts for the close ties that have always existed between the Academy and the Government, although the Academy is not a governmental agency and its activities are not limited to those on behalf of the Government.

THE NATIONAL ACADEMY OF ENGINEERING was established on December 5, 1964. On that date, the Council of the National Academy of Sciences, under the Authority of its Act of Incorporation, adopted Articles of Organization bringing the National Academy of Engineering into being, independent and autonomous in its organization and the election of its members, and closely coordinated with the National Academy of Sciences in its advisory activities. The two Academies join in the furtherance of science and engineering and share the responsibility of advising the Federal Government, upon request, on any subject of science or technology.

THE NATIONAL RESEARCH COUNCIL was established in 1916, at the request of President Woodrow Wilson, by the National Academy of Sciences to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and of advising the federal government. The Council operates in accordance with general policies determined by the Academy by authority of its Congressional charter of 1863, which establishes the Academy as a private, non-profit, self-governing membership corporation. Administered jointly by the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine (all three of which operate under the charter of the National Academy of Sciences), the Council is their principal agency for the conduct of their services to the government, the public, and the scientific and engineering communities.

Supported by private and public contributions, grants, and contracts, and voluntary contributions of time and effort by several thousand of the nation's leading scientists and engineers, the Academies and their Research Council thus work to serve the national interest, to foster the sound development of science and engineering, and to promote their effective application for the benefit of society.

THE COMMISSION ON ENGINEERING AND TECHNICAL SYSTEMS is one of the major components of the National Research Council and has general responsibility for and cognizance over those program areas concerned with the development and application of the engineering disciplines to technological and industrial systems, and their relationship to problems of both national and international significance.

THE MARINE BOARD is an operating unit of the Commission on Engineering and Technical Systems of the National Research Council. The Board addresses issues of current and continuing importance to the government and the nation in ocean resources and maritime transporation development; coastal, port and harbor, and inland waterway use; support of science; and national and international cooperation and information exchange.

MARINE BOARD PUBLICATIONS

Documents indicated by AD or PB numbers can be purchased from the National Technical Information Service (NTIS) 5285 Port Royal Road, Springfield, VA 22161; for more information call (703) 487-4780. Those reports with ISBN numbers are available from the National Academy Press, 2101 Constitution Avenue, N.W., Washington, DC 20418, (202) 334-3113. All other reports are available from the Marine Board, 2101 Constitution Avenue, N.W., Washington, DC 20418, (202) 334-3119.

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Proceedings of the Future Maritime Leaders' Seminar, 1982, 74 pp., available from the Marine Board

Critcal Issues in Maritime Transportation, 1982, 26 pp., ADA 120744

Marine Salvage in the United States, 1982, 141 pp., ADA 119851

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Productivity Improvements in U.S. Naval Shipbuilding, 1982, 87 pp., ADA 123958

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Criteria for the Depths of Dredged Navigational Channels, 1983, 137 pp., ADA 135628

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